THE NEED FOR A REHABILITATION PROGRAM FOR WATER DISTRIBUTION AND SEWAGE COLLECTION SYSTEMS IN ONTARIO

FINDINGS OF A CANADA WORKS PROJECT STUDY

J. C. ELSTAD
STUDY SUPERVISOR

- JANUARY 1987 -

EXECUTIVE SUMMARY

For some time now, the Ontario Ministry of the Environment has been working to develop a program to encourage the rehabilitation of the watermain and sewer infrastructure in Ontario. The Ministry has made considerable progress in this regard. The central idea fueling the desire for such a program is the conviction that the combination of the extensive growth of water and sewer services in Ontario, recent government restraint and the fact that these services are buried and therefore out of sight has lead to a deferral of necessary work on watermain and sewer infrastructure and a backlog of maintenance and replacement.

A rehabilitation program would address this backlog (of necessary work) with considerable savings to the Province. Rehabilitation refers to a variety of in-situ techniques for restoring the capacity of, or extending the useful life of, watermains or sewers, but may also include, where appropriate, repair or replacement.

This report presents the findings of a study that sought to assess the need for a rehabilitation program in Ontario by determining the age and condition of the Province's water distribution and sewage collection systems. To this end, data were gathered for water and sewer systems serving 80% of the entire serviced population in Ontario. To a lesser extent, the study also sought to discover any special problems with respect to implementing a rehabilitation program in Ontario's smaller municipalities. In this regard, detailed information was gathered during visits to over 70 small Ontario municipalities.

The principal findings are as follows.

1. Approximately 25% of the province's watermains and sewers are presently over 50 years old. An outside estimate (or worst case scenario) for the cost of the backlog of necessary work would be the cost of replacing, over the next 50 years, all the watermain and sewer in the province that is currently over 50 years old. The estimate of this cost is $150 million per year for the next 50 years.

   However, a rehabilitation program will be able to address the backlog of necessary work at considerably less expense than total replacement. Furthermore, some major rehabilitation work is already under way, especially in large municipalities. Therefore, the new, incremental investment required in the Province for the rehabilitation of water distribution and sewer systems is estimated to be about $100 million per year over the next 50 years.

2. Many water distribution systems in Ontario are suffering very high rates of watermain breakage as expressed as breaks/100 km/year. The average watermain break rate in Ontario is approximately 25 breaks/100 km/year. If, as a result of a rehabilitation program, the average break rate across the Province could be reduced to 10 breaks/100 km/year, the savings in watermain break repair could be close to $15 million per year.

3. For water distribution systems across the Province the average for "unaccounted for water" as a percentage of total flow is 12.5%. If one quarter of these losses could be eliminated as a result of a

Province-wide rehabilitation program, the yearly savings in water treatment costs are estimated to be almost $5 million.

4. Many sewer systems across the Province have inflow and/or infiltration problems which can lead to heightened sewage treatment costs, reduced sewage treatment efficiency, spills of untreated sewage to the environment and the flooding of basements with sewage. 147 sewage collection systems across the province are known to have inflow and infiltration problems. It is assumed that extraneous flows due to inflow and infiltration represent 21% of total flows for these systems. If one half of the extraneous flows due to inflow and infiltration in the Province's sewer systems could be eliminated through the introduction of a rehabilitation program, the annual savings in sewage treatment costs could be as great as $6.4 million.

5. It is estimated that there are at least 4,700 km of combined sewer remaining in the Province. The current cost to provide storm relief sewers for all these combined sewers is $2.85 billion.

6. Small Ontario municipalities would welcome such a rehabilitation program. Historical inventory and service records in these municipalities are generally poor, but these municipalities often have a very good idea of the current needs of their systems. The elimination of certain types of inflow from sewer systems can be very expensive, and as a result presents a difficult problem for small Ontario municipalities. These municipalities would welcome increased co-ordination between Ministries of the Ontario Government that provide programs that affect

municipal public works infrastructure, because they believe that increased co-ordination would enable them to accomplish still more work with the limited funds available.

ACKNOWLEDGEMENTS

Many people and organizations contributed to making this report possible. Special recognition and thanks are owed to the following.

The salaries of the exceptionally bright group of people that formed the staff for this project were provided by the Federal Department of Manpower and Immigration as part of what was called, at that time, a "Canada Works Project".

Phil Joseph of the Ontario Ministry of the Environment acted as Project Manager throughout the course of this project and provided valuable guidance. Dr. G.W. Heinke of the University of Toronto acted, at one time, as a sponsor of the project and was an Advisor throughout the project.

This report, of course, would not have been possible without the contributions of the project staff. The members of this staff were (in no particular order): Rudy D'Agostino; Cropthorne Lee; Will Heywood; Elio Covello; Richard Bennett; Richard Chiu; and Dominic Nigro.

At certain times the advice or other help provided by certain individuals has proved very important. At the Ontario Ministry of the Environment C.J.K. Wilson provided vital encouragement, while C.E. McIntyre, C.E. Letman, C.W. Brink and W. Smithies all provided excellent advice. C.D. Mialkowsky and D. Atkinson provided operating costs for MOE operated water and sewage plants. Professors P.H. Byer and B.J. Adams of the University of Toronto are gratefully acknowledged for their help and suggestions.

The preparation of this report was greatly facilitated by the hard work of G. Keys, who checked the data and participated in its analysis and presentation.

Finally, and most importantly, the municipalities and municipal officials that took the time and trouble to provide the information that is the substance of this report are gratefully acknowledged.

TABLE OF CONTENTS

EXECUTIVE SUMMARY (i)

ACKNOWLEDGEMENTS (v)

1.0 INTRODUCTION 1

1.1 Purpose of This Report 1

1.2 Scope of This Report 1

1.3 Background 2

1.4 The Need for a Rehabilitation Program in Ontario 4

1.5 Extent of Rehabilitation Activities in Small Ontario Towns 4

1.6 Significance of This Research 5

1.7 Structure of This Report 6

2.0 NEED FOR A REHABILITATION PROGRAM 7

2.1 Extent of Response To The Questionnaire 7

2.2 Age of Ontario Water and Sewer Piping Systems 9

2.3 Condition of Ontario Water Distribution Systems 18

2.4 Condition of Ontario Sewer Systems 32

2.5 Concerns of Ontario Municipalities 41

3.0 THE SITUATION IN SMALL ONTARIO MUNICIPALITIES 46

3.1 The State of Current Information on Water and Sewer Systems 46

3.2 Cost and Extent of Current Maintenance and Rehabilitation Activities 48

3.3 Sewer Use By-Laws 52

3.4 A Special Consideration 55

4.0 REFERENCES 56

APPENDICES

LIST OF FIGURES

		Page
1.	Number of Responses by Region	9
2.	Responses by Serviced Population	9
3.	Maximum Age of Ontario Systems	13
4.	Watermain and Sewer Pipe Ages	13
5.	Watermain Break Rates - No. of Systems in Each Break Rate Category	21
6.	Watermain Break Rates - Percent of Systems Per Break Rate Category	21
7.	Watermain Break Rates - Break Rates According to Population	23
8.	Break Rate by Region	23
9.	Watermain Breaks - Most Common Reasons for Breaks	26
10.	Unaccounted for Water - No. of Systems vs. Amount Unaccounted	29
11.	Unaccounted for Water - Percent of Systems vs. Amount Unaccounted	29
12.	Sewage Collection Systems - Reasons for Infiltration	35
13.	Sewage Collection Systems - Reasons for Inflow	35
14.	Water Distribution Systems - Areas of Primary Concern	42
15.	Water and Sewer Systems - Present Condition	43
16.	Water and Sewer Systems - Change in Condition Over 15 Years	43

LIST OF TABLES

		Page
1.	An Outside Estimate of the Cost of Rehabilitating the Province's Watermains	15
2.	An Outside Estimate of the Cost of Rehablitating the Province's Sewers	16
3.	An Estimate of the Savings Resulting From A Reduction in the Rate of Watermain Breakage in Ontario	20
4.	An Estimate of the Savings Resulting from A ¼ Reduction in Unaccounted for Water in Ontario	31
5.	Cost of Treating Extra Flows	40
6.	Average Maintenance and Rehabilitation Costs (Water and Sewer Systems)	50
7.	Existence and Enforcement of Sewer Use By-Laws (in 25 Small Municipalities With Inflow Problems)	53

1.0 INTRODUCTION

1.1 Purpose of This Report

The purpose of this report is to present the results of a study undertaken between August 1985 and January 1986 which assessed the need for a rehabilitation program for water and sewer piping systems in Ontario. In order to assess this need, the study sought to determine the age and condition of these underground piping systems. In addition, the results of another aspect of the study are presented which investigated, for small Ontario municipalities, the quality of detailed information available with respect to water and sewer piping systems and the extent of current maintenance and rehabilitation activities for these systems.

1.2 Scope of This Report

This report focuses on watermains and sewers and does not address the age or condition of "above ground" facilities such as treatment works, pumping stations, appurtenances, etc. The reason for this is that inadequate attention has been paid to repair and renewal of watermain and sewer infrastructure in the past. Because these facilities are buried underground, they are easily ignored. (Indeed, watermains and sewers have been called "Invisible Infrastructure".) The extensive growth of these services, coupled with recent government restraint, has led to the deferral of much necessary work. Data concerning watermains and sewers are often inadequate. The value of these facilities and their

importance to the standard of living expected in an urban environment is sometimes misunderstood.

1.3 Background

This consideration of the need for a rehabilitation program for water and sewer piping systems in Ontario comes at a time of increasing public awareness of the problems of aging and consequently deteriorating public works infrastructure in North America. In the United States, events such as the collapse of the Myannis River bridge in Connecticut, the failure of the Newark Water System, and the publication of "America in Ruins" [1], to mention just a few examples, stimulated the growth of interest in public works infrastructure. One result of this heightened interest was the recent imposition in the United States of a federal tax on gasoline intended to raise funds for road renewal.

Paralleling this activity in Canada, the Federation of Canadian Municipalities commissioned a study, "Canada's Urban Infrastructure: Condition and Funding Adequacy" [2], which attempted to document the needs of Canada's urban infrastructure and the inadequacy of current funding.

For sometime, the Ontario Ministry of the Environment has been keenly aware of the problems of aging water and sewer piping systems in Ontario. With respect to watermains, these problems include accelerated rates of breakage and leakage that can cause financial hardship and disruption of service for Ontario municipalities. In addition, aged watermains can contribute to the deterioration of water quality in municipal distribution systems by harbouring

bacterial growth. Problems with sewers can lead to premature wear and tear on equipment and facilities, increased operating expenses, and sewage overflows causing pollution of the environment.

As well, the MOE has been concerned that the cost of, and the extent of the problem of, repairing and renewing Ontario's very extensive water and sewer servicing are not well understood. As a result, the repair and renewal of these systems are being, in effect, postponed into the future. If the process of rehabilitating these systems on an adequate scale were begun soon, considerable savings in current operating and repair costs could be achieved. Also, significant savings could be realized in the cost of replacing the aged parts of water distribution and sewage collection systems, if it were possible to extend the useful life of these aged system components.

A rehabilitation program would encourage the use of various currently available, in-situ techniques to restore the capacity of, or extend the useful life of, watermains and sewers. Repairs or replacements, where they are the preferred alternatives, may also be part of a rehabilitation program. Such terms as renovation or renewal may also describe activities that would fall under the umbrella of a rehabilitation program.

As a result of these concerns, the MOE commissioned James MacLaren in 1983 to prepare a "Report to the Ministry of the Environment of the Province of Ontario on a Water Distribution and Sewerage Rehabilitation Program for Ontario Municipalities" [3]. MacLaren estimated that the replacement value

of Ontario's water and sewer pipes and associated appurtenances was $31.5 Billion and that approximately $285 Million should be spent yearly on their repair, renovation and replacement.

1.4 The Need for a Rehabilitation Program in Ontario

It was decided to assess the need for a rehabilitation program by documenting the age and condition of the water and sewer piping systems in Ontario. With this aim in mind a short questionnaire was developed for mailing to every municipality in Ontario with a public communal water or sewer system. (An example of this questionnaire can be viewed in Appendix 1.)

The staff of a Canada Works Project was asked to contact every municipality in the Ontario Municipal Directory to determine whether or not there were public, communal water distribution or sewer systems in the municipalities. Questionnaires were then mailed to municipalities with the aforementioned systems. A computerized database was developed with the information provided in the returned questionnaires.

1.5 Extent of Rehabilitation Activities in Small Ontario Towns

The study sought to determine if there were any special problems or considerations with regard to implementing a rehabilitation program for the smaller municipalities in Ontario. The staff involved in the same Canada Works Project (mentioned above) visited 75 Ontario municipalities, most of which had populations of less than 7,500 although a few had

populations between 7,500 and 25,000. The staff collected the information necessary to complete a detailed inventory form that had been prepared by the MOE. The process of collecting this information allowed the staff:

1. To learn the quality of detailed information available with regard to water distribution and sewage collection systems in small municipalities;

2. To determine the cost and extent of current rehabilitation and maintenance efforts in these small municipalities; and

3. To discover any special problems with regard to implementing a rehabilitation program in these municipalities.

1.6 Significance of This Research

The information presented in this report was gathered through relying on the goodwill and understanding of officials in Ontario municipalities. The data, therefore, have the advantage of reflecting the true concerns of Ontario municipalities as expressed by municipal officials themselves and of benefiting from these municipal officials' "hands on" experience with their own systems. Every effort has been made to ensure that the data accurately reflects the information as provided by the municipalities.

This study is relatively unique in that there are few studies currently in existence reporting on the age and condition of all the systems in a diverse

jurisdiction (such as Ontario). Most existing studies focus on one or more large urban centres.

1.7 Structure of This Report

The first topic discussed is the extent of the response to the questionnaire on the age and condition of water distribution and sewer systems. This will help the reader judge the applicability of the conclusions drawn in this report to all of Ontario.

Subsequent to this, the age of these Ontario systems is discussed and then the condition of water distribution and sewer systems. Next, the concerns of the operating authorities themselves and their opinion of the condition of their systems is considered. Conclusions are drawn as warranted.

Finally, the situation in small Ontario municipalities is discussed: the quality of information available on water and sewer systems; costs of current maintenance and rehabilitation activities, and; enforcement of Sewer Use By-Laws.

2.0 NEED FOR A REHABILITATION PROGRAM

2.1 Extent of Response To The Questionnaire

There are 839 municipalities in Ontario but, of course, not all of them have public, communal water or sewer systems. In 1981 there were 7,520,000 people in Ontario in 401 municipalities serviced by communal water systems [4]. In the same year there were 6,580,000 people in Ontario residing in 335 municipalities serviced by communal sewer systems.

Although a serious attempt was made to encourage all municipalities with public, communal water distribution or sewer systems to respond to the questionnaire, the rate of response fell short of 100% (as was expected). The results presented in this report are based upon questionnaires returned by municipalities for sewer systems in 286 municipalities with a total serviced population of 5,620,115 and for water systems in 344 municipalities with a total serviced population of 5,904,515.

Most of the population in Ontario that is serviced by these systems is represented in the database of returned questionnaires. More recent (1984) figures [5] indicate that 7.5 M people in Ontario are serviced by communal water systems. The returned questionnaires represent 78.73% of this serviced population. The same 1984 figures indicate that the sewer serviced population in Ontario is 7.1 M. The returned questionnaires represent 79.16% of this serviced population.

It is important to note that there are more systems than municipalities in the database of returned questionnaires. One of the objectives of this study was to determine the age and condition of individual, identifiable water and sewer piping systems. However, some municipalities contain a number of individual communities with their own individual communal water or sewer systems. Therefore, it is possible to have a number of water or sewer systems in one municipality. Because of this, the results presented here represent responses for 477 water systems in 344 municipalities. In the same fashion the results presented here represent 330 sewer systems in 286 municipalities. (The total number of systems represented in the various graphs in this report may vary as a result of missing data elements.)

Figure 1 is a graphic presentation of the returned questionnaires categorized according to the MOE Region in which the systems can be found. It can be seen that there is good representation from every region of the province. The fewest number of responses were received from the Northwest Region (24 water systems and 20 sewer systems). However, since there are only 27 water treatment facilities in this sparsely populated region and 23 sewage treatment facilities it can be said that most of the systems in this region are represented in the results [5].

On the other hand, it can be seen from Figure 1 that 155 water systems and 98 sewer systems in the Southwest Region are represented in the results despite the fact that there are only 95 water treatment facilities and 101 sewage treatment facilities in the Southwestern Region [5]. This seemingly paradoxical result is explained by the fact

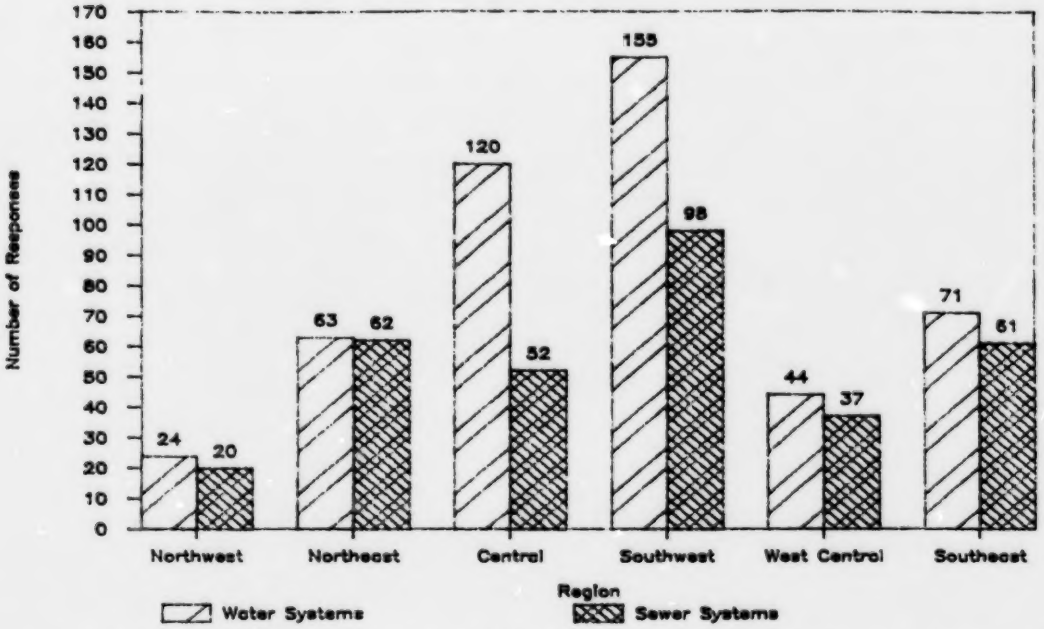

Fig. 1. Water and sewer systems in the database of returned questionnaires categorized by MOE region.

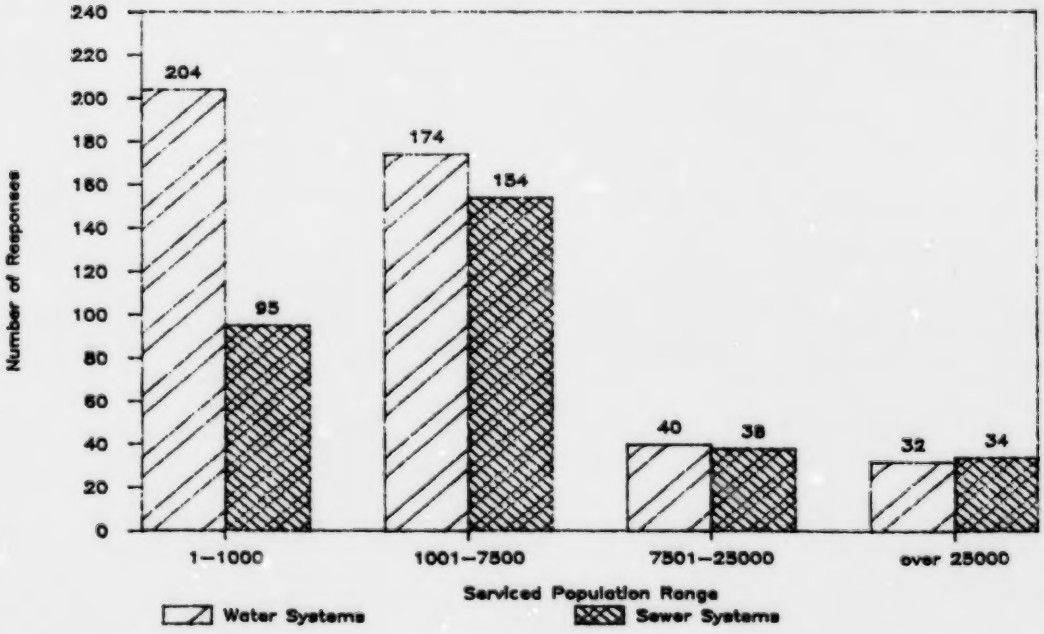

Fig. 2. Water and sewer systems in the database of returned questionnaires categorized according to serviced population.

that there are a large number of small, identifiable water or sewer piping systems in communities in this Region that are connected to large treatment facilities (e.g. area schemes).

Figure 2 represents a categorization of the water distribution and sewer systems in the database of returned questionnaires according to the populations which they service. It can be seen that there are a large number of small systems (204 water systems and 95 sewer systems) serving populations of less than 1,000. On the other hand there are relatively few large systems (32 water systems and 34 sewer systems) serving populations of over 25,000. The key point here is that this distribution of systems according to their serviced population mirrors the distribution of municipalities in Ontario according to population. In Ontario, there are a great number of small municipalities and a small number of large municipalities. Therefore, the results presented here should reflect a reliable cross-section of Ontario.

From the foregoing it can be seen that the information provided in the returned questionnaires should give a good idea of the age and condition of water distribution and sewer systems in Ontario.

2.2 Age of Ontario Water and Sewer Piping Systems

Information on the age of a water distribution or sewer system does not constitute a sufficient basis in itself on which to form an opinion of the condition of a system. It is generally known that some watermains, depending on circumstances, can have a useful life of over 100 years while other watermains may have a useful life of less than 40

years. Nevertheless, on a broad scale (such as for all the water distribution and sewer systems in Ontario), age is still the best single indicator available of the possible need for investment in rehabilitation of these systems. The greater the age of a system, the greater is the exposure of the system to such deterioration promoting factors as frost action, erosion, ground settlement, etc.

The average age of water distribution systems in Ontario has been estimated in previous work at 40 years, while the average age of sewer systems in Ontario has been estimated at 30 years [3]. However, for this study it was decided that it would be too difficult to determine the average age for these systems. Water distribution and sewer systems are composed of many smaller parts of different sizes that were constructed at various times. For many municipalities, information on the specific ages of pipe sections is often non-existent. To determine the average age of an entire system would have been a difficult task, too difficult to expect the municipalities responding to the questionnaire to determine in the time allowed.

Therefore, two methods were employed in the questionnaire to deal with this problem of gathering information on the age of water distribution and sewer systems. One section of the questionnaire requested the age of the oldest section of the water distribution and sewer systems. This is similar to setting the age of a house according to the year in which it was constructed regardless of whether or not many additions have been made to the house in subsequent years or whether or not most of the house has been renovated. The results of this section of

the questionnaire provide information on the age of Ontario systems according to the age of their oldest parts. (Accordingly, the age of Toronto's water system would be at least 100 years because some of the watermains in the downtown core are over 100 years old.)

Figure 3 shows the age of Ontario water distribution and sewer systems according to the age of their oldest sections. Not surprisingly, the graph shows that a large number of water systems and particularly sewer systems have been constructed since World War II. Nevertheless, 151 water systems and 92 sewer systems were constructed over 50 years ago. Since so many systems have very old sections, it is probable that there will be a need for a great deal of rehabilitation work in the near future.

The other approach taken to determining the age of water distribution and sewer systems in the Province was to ask in the questionnaire what percentage of each system fell into the 25-50 year age category and what percentage fell into the greater than 50 year age category. It was assumed that the municipalities could more easily and accurately state the percentage of pipe in certain age ranges, than they could estimate a precise average age.

Using information provided elsewhere in the questionnaire, it is possible to determine for all the watermain and sewer pipe for which information was provided, and by inference for all the pipe in Ontario, the percent of watermain and sewer, that is over 50 years old, the percent that is between 25 and 50 years old, and the percent that is less than 25 years old.

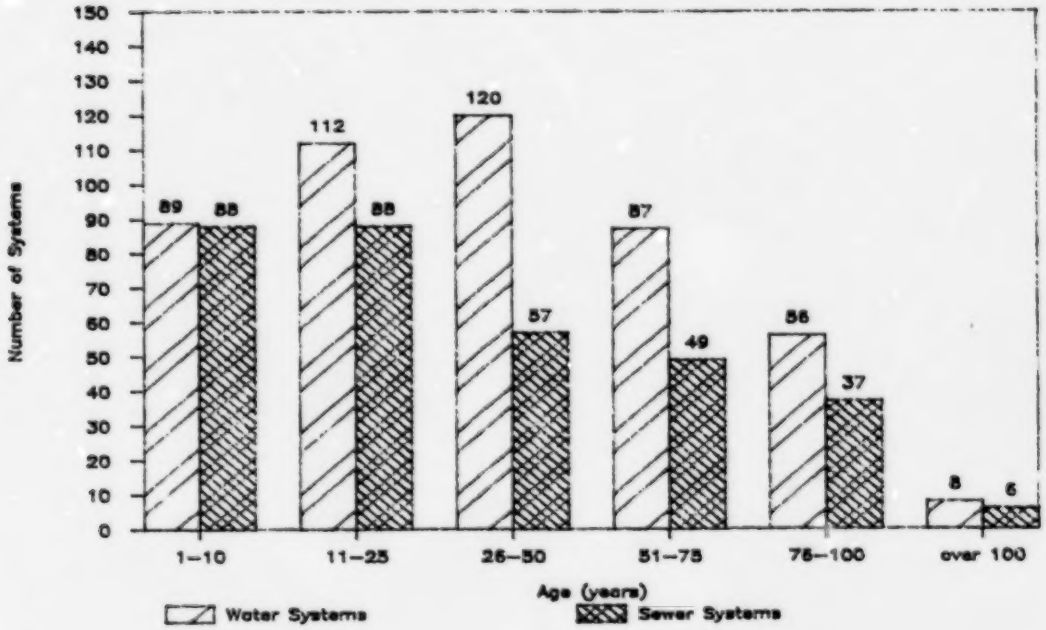

Fig. 3. Water and sewer systems categorized according to the age of the oldest section of each system.

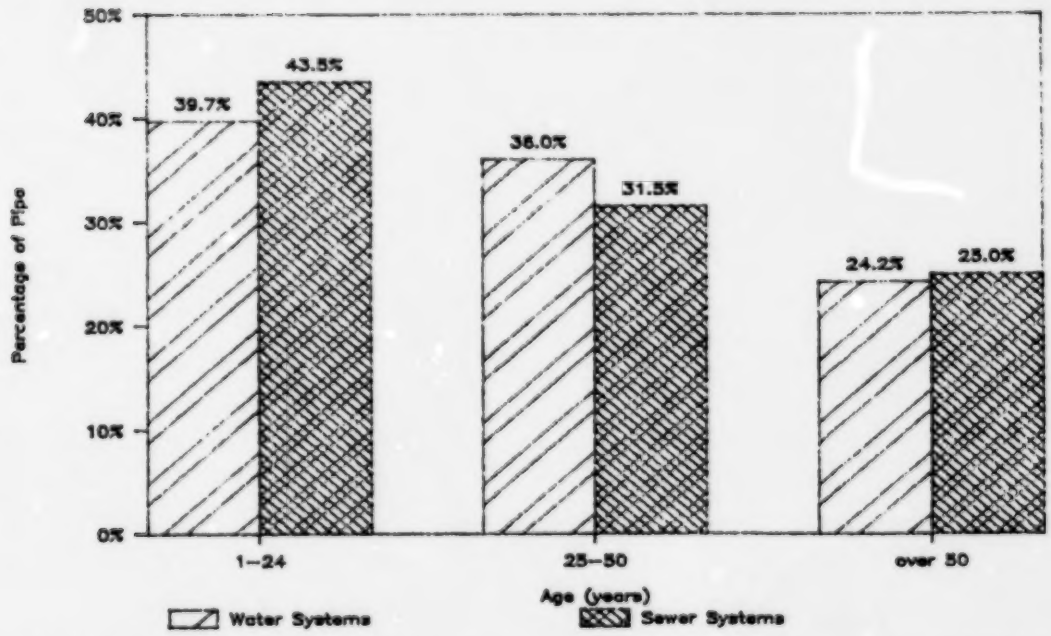

Fig. 4. The percentage of watermain and sewer pipe falling into the above age ranges.

The results of this part of the analysis of the age of Ontario systems are shown in Figure 4. It can be seen from this graph that 24.2% of all the watermain in the database is over 50 years old. 25% of the sewer in the database is over 50 years old. On the other hand, most of the pipe in the database, and by inference in the Province, is less than 25 years old. 43.5% of the watermain and 39.7% of the sewer are less than 25 years old.

Estimating the Cost of a Rehabilitation Program

One way to arrive at an outside estimate of the cost of a rehabilitation program (to bound the problem) would be to assume that all the pipe in the Province that is currently over 50 years old will need to be replaced within the next 50 years. (Some of the pipe that is currently over 50 years old is, in fact, as old as 100 years. So, under this assumption, pipe can be between 50 and 150 years old at its time of replacement.) Of course, all of this pipe will not need replacement over this period of time, but then a certain amount of pipe currently less than 50 years old will need replacement instead. It is assumed that the amount of pipe having a longer than expected lifespan will equal the amount of pipe having a shorter than expected lifespan.

Under these assumptions the total annual cost for the rehabilitation of watermain and sewer in the Province over the next 50 years should be at most $150 million. The derivation of this amount is demonstrated in Table 1 for water distribution systems and in Table 2 for sewage collection systems.

Table 1: An Outside Estimate of the Cost of Rehabilitating the Province's Watermains

The total length of watermain in the database of returned questionnaires is 26,314 km. 24.2% of this watermain or 6,368 km is over 50 years old.

The current cost of replacement is:

6,368 km x $475,000/km[1] = $3,024,800,000.

This cost can be expressed in terms of equal annual amounts over the next 50 years. (This is equivalent to using a discount rate of Ø%.) The annual cost would be:

$3,024,800,000 ÷ 50 years = $60,496,000/year.

Since the database of returned questionnaires represents only 78.73% of the population serviced by communal water systems in Ontario, the annual cost over the next 50 years of replacing all the watermain in the Province that is more than 50 years old would be greater. This annual cost (an outside estimate of the cost of rehabilitating the Province's watermains) would be:

$60,496,000 x 1.27 = $76,829,920.

---

[1]This unit cost of replacement is taken from MacLaren [3] and includes the replacement of mains (average diameter - 200 mm), hydrants, valves (average diameter - 200 mm) and service connections (average length - 20 m, average diameter - 19 mm). It is also scaled up by 50% for contingencies.

Table 2: An Outside Estimate of the Cost of Rehabilitating the Province's Sewers

The total length of sewers for the population serviced in this database is:

5,620,115 persons ÷ 220 persons/km = 25,546 km.

25% or 6,386 km of these sewers are over 50 years old. The current cost of replacement for this sewer is:

6,386 km x $454,000/km[1] = $2,899,244,000.

The annual cost over 50 years is then:

$2,899,244,000 ÷ 50 years = $57,984,880/year.

Since this database represents only 79.16% of the total sewer serviced population in Ontario, the annual cost over the next 50 years of replacing all the sewer in the Province that is currently more than 50 years old would be greater. This annual cost (an outside estimate of the cost of rehabilitating the Province's sewers) would be:

$57,984,880 x 1.26 = $73,060,949.

---

[1]This unit cost is taken from MacLaren [3] and includes the cost of replacement for sewers (average diameter 250 mm, 3 m dig), manholes (3 m dig), service connections (average length - 20 m, average diameter - 150 mm) and lift stations (average depth - 8 m). To allow for contingencies, the sewer cost is scaled up by 75%, while the other component costs are scaled up by 50%.

Of course, requirements for new capital investment for the rehabilitation of watermain and sewers in the Province should be less than this $150 million estimate of the cost of replacement. This is because some major rehabilitation of these systems is already underway, particularly in large municipalities. Furthermore, rehabilitation of aged and deteriorated system components should provide considerable savings over replacement. Therefore, the new capital investment in the Province necessary for the rehabilitation of watermain and sewer infrastructure could be as low as $100 million/year.

The estimate developed here that at most $150 million/year should be spent on the rehabilitation of watermains and sewers is considerably less than James MacLaren's estimate [3] that $285 million should be spent annually. However, this lower figure was arrived at using new information and different assumptions.

For the sake of simplicity, this estimate of the cost of a rehabilitation program has not taken into account the effect of government borrowing or the effect of inflation. These factors would have increased the estimated annual cost. Also, due to the non-uniform distribution of watermains and sewers according to their age in Ontario (see Figure 4 - there are more new facilities than old facilities), the required spending level may need to increase some time from now as the newer facilities age.

2.3 Condition of Ontario Water Distribution Systems

Information was provided in the returned questionnaires on the total length of watermain in the systems, the number of watermain breaks per year, the most common watermain material and the percentage of the total flow that is unaccounted for. This information is used here to assess the condition of Ontario's water distribution systems. For purposes of this discussion, the criteria for judging the condition of these systems are the rate of watermain breakage and the rate of water losses.

Rate of Watermain Breakage

For the sake of comparing rates of watermain breakage for different water distribution systems, it is customary to express the break rate as the number of breaks per 100 km per year. In this fashion, James MacLaren [3] estimated that the average break rate across Ontario was 25 breaks/100 km/year. He also suggested that this average rate was higher than necessary and that an average break rate across the Province of 10 breaks/100 km/year could be achieved through good practice in design, construction and maintenance. For the water distribution systems represented in the database of returned questionnaires, a total of 6,497 watermain breaks per year were reported. This represents an average of 24.7 breaks/100 km/year, surprisingly close to MacLaren's estimate.

If an average rate of watermain breakage of 10 breaks/100 km/year across the Province could be

achieved through a rehabilitation program, then the savings in expenditures on the repair of watermain breaks in Ontario would be $14,728,000 per year. The derivation of this amount is presented in Table 3.

With reference to Figure 5, it can be seen that 325 of the water distribution systems in the database reporting on the length of their systems were experiencing breaks. 111 water distribution systems reported no breaks at all. Of the systems reporting breaks, more systems fell into an interval of break rates between 11 and 25 breaks/100 km/year than into any other interval. Of particular concern, however, is the large number of systems with very high rates of watermain breaks. 78 systems had break rates over 50 breaks/100 km/year. (43 systems in the 51 to 100 breaks/100 km/year category plus 35 systems in the greater than 100 breaks/100 km/year category.) In Figure 6 the percentage of these systems in the different break rate categories is depicted. Of the water distribution systems in the database which are experiencing breaks, 24% have break rates greater than 50 breaks/100 km/year. (13.2% of the systems have break rates between 51 and 100 breaks/ 100 km/year and 10.8% of systems have break rates greater than 100 breaks/100 km/year.)

The severity of this problem of high rates of watermain breakage in Ontario communities is mitigated by the fact that many of the water distribution systems with high break rates are very small. Figure 7 demonstrates the number of water distribution systems serving at most 7,500 people and the number of systems serving more than 7,500 people for each break rate interval. For example, for the

Table 3: An Estimate of the Savings Resulting from a Reduction in the Rate of Watermain Breakage in Ontario

The total cost per year to repair the watermain breaks reported for the systems in this database is:

6,497 breaks x $3,000/break = $19,491,000.

The total cost per year at the lower rate of breakage would be:

10 breaks/100 km x 26,314 km x $3,000/break
= $7,894,000.

The savings per year if a lower rate of breakage were achievable would be:

$19,491,000 - $7,894,000 = $11,597,000.

Since the database does not include all the water distribution systems in the Province, the savings per year across the Province if a lower rate of breakage were achievable would be:

$11,597,000 x 1.27 = $14,728,000.

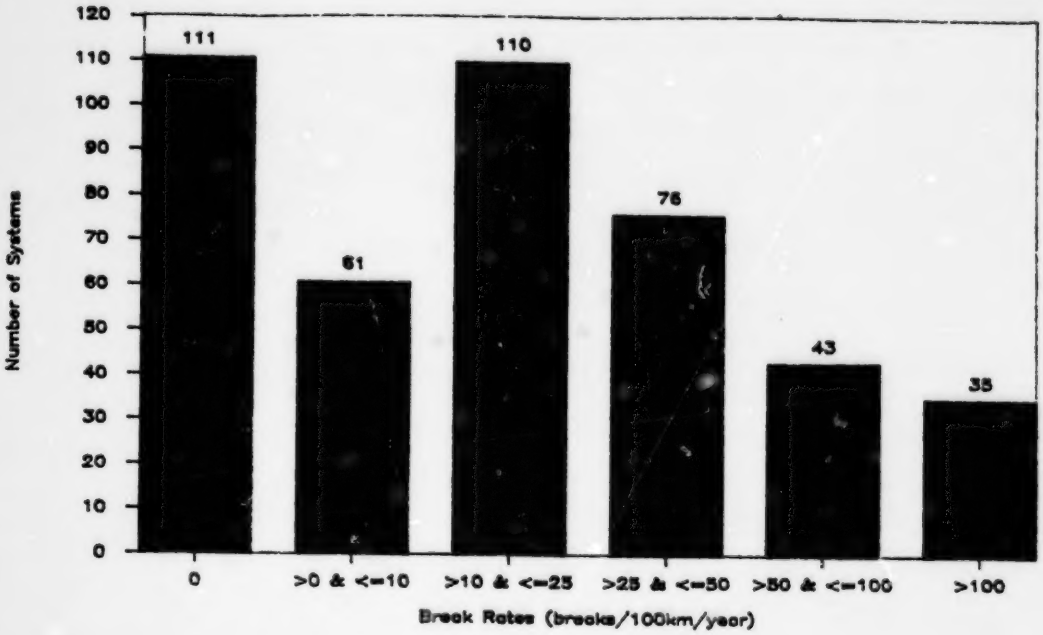

Fig. 5. The distribution of break rates for water distribution systems.

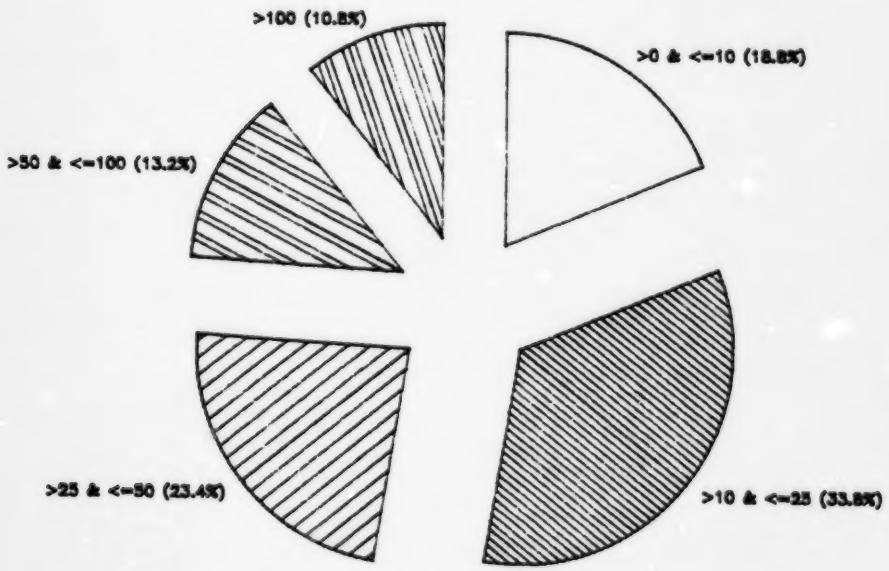

Fig. 6. The percentage of water distribution systems falling into the above break rate categories for those systems reporting breaks.

61 water distribution systems experiencing breaks at rates no greater than 10 breaks/100 km/year, 41 have serviced populations no greater than 7,500. 20 have serviced populations greater than 7,500. For the 35 water distribution systems with break rates greater than 100 breaks/100 km/year, 34 of the systems serve populations no greater than 7,500. (In fact, 27 of these water distribution systems serve populations no greater than 1,000.)

A high rate of watermain breakage in a very small community may not be as severe a problem as it may seem. For a hypothetical small community with a water distribution system 2 km in total length and serving approximately 400 people, a watermain break history of 2 breaks/year would be equivalent to a break rate of 100 breaks/100 km/year. Although this is a very high rate of breakage, the yearly cost of repairing these breaks would not be too burdensome ($6,000/year at $3,000/break). Moreover, the watermain breaks in this hypothetical community could be due to isolated, temporary phenomena occurring in one bad stretch of pipe. The replacement of this stretch of pipe could result in a period of many years without breaks throughout the small system.

Notwithstanding the foregoing discussion, it would seem from the high numbers of small communities with high rates of watermain breakage that there is a problem in Ontario due to the location of small water distribution systems in conditions that are probably adverse. This leads to a disproportionate share of local resources being spent on the more or less constant repair of the water distribution system, and suggests a worsening and potentially serious problem in the future.

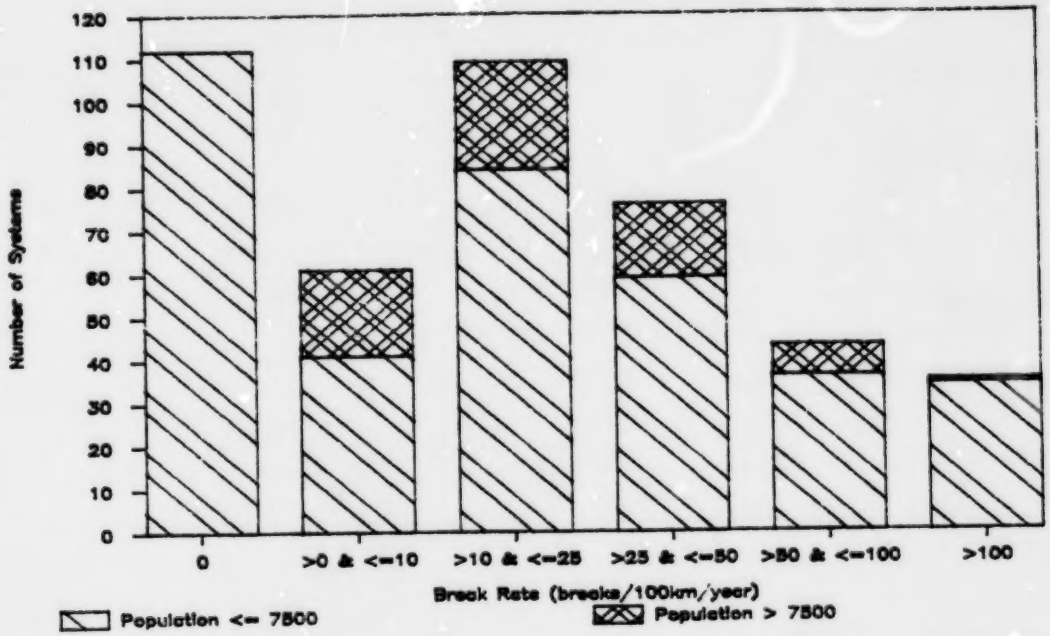

Fig. 7. The distribution of watermain break rates further categorized according to system size (serviced population).

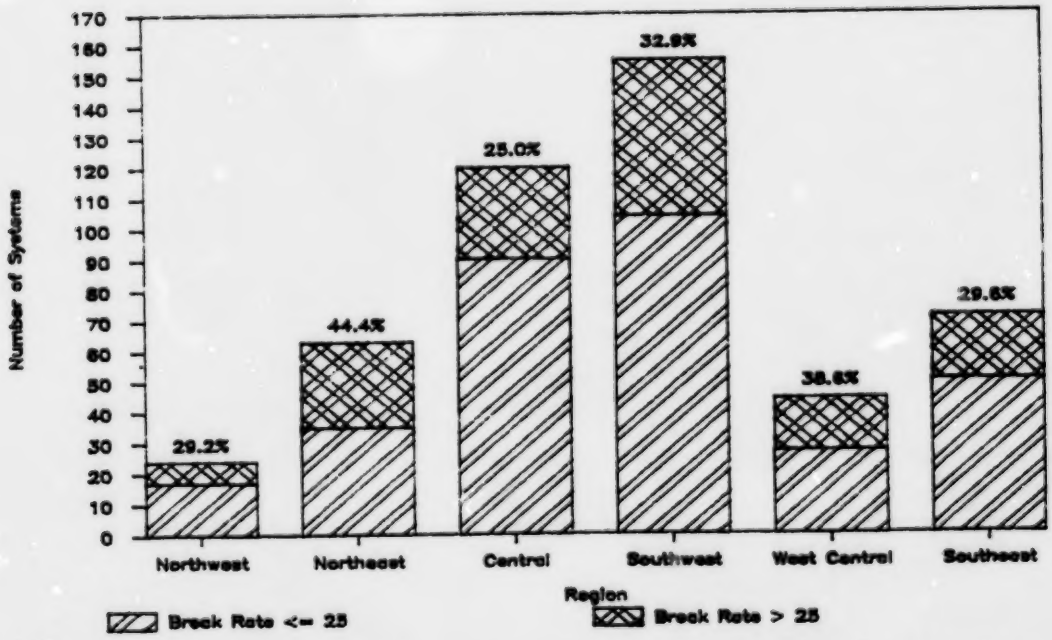

Fig. 8. The number of water distribution systems with high or low break rates for each MOE region.

In Figure 8, the number of systems in each region reporting high rates of watermain breakage (greater than 25 breaks/100 km/year) and low rates of watermain breakage (at most 25 breaks/100 km/year) are shown. At the top of each bar the percentage is shown that the number of systems with high rates of breakage represents to the total number of systems reporting breaks in a region. From these percentages it would appear that the most severe problems occur in the Southwest, West Central and Northeast regions (32.9%, 38.6% and 34.4% respectively of the systems reporting breaks in these regions, report high rates).

It may be suggested that the large number of systems with high rates of watermain breakage in the Southwest region may be due to the relatively large number of small systems there. (As explained above, watermain break rates in small communities may be statistically impressive but not pose a severe problem.) The large number of systems in the Northeast region with high rates of breakage may be explained both by the presence of small systems there and by adverse conditions such as severe winter temperatures and the necessity of constructing many of the systems in rocky terrain.

Overall, the watermain breakage problem is worse in the North than in the South. The average rate of watermain breakage for the two Northern regions is 28.7 breaks/100 km/ year while the average rate in the four Southern regions is 24.2 breaks/100 km/year.

Reasons for Breaks

Watermain failures can occur in a number of ways. There are beam failures which appear as circumferential breaks which can be caused by a loss of pipe bedding support and occur primarily in small diameter watermains. There can be longitudinal breaks along the pipe length due to crushing loads from above which occur more often in large diameter watermains. There can also be pin hole or blow out breaks due primarily to corrosion or material failure [6]. (This discussion is not meant to be exhaustive - there are other types of watermain breaks such as separation at bends and tees.)

These types of watermain failures have various causes and as a result the range of responses concerning the major reasons for watermain failure in the returned questionnaires was very broad. For ease of analysis, the responses have been grouped into several categories which are shown in Figure 9.

The most common reason given for watermain breaks is frost (28.9% of responses). This category includes all temperature effects, but the most common responses by far in this category were frost, or frost heave, or frost jacking. The prevalence of frost as a reason for watermain breaks should not be surprising given the large numbers of systems in Ontario constructed in rocky terrain and/or subjected to severe winter temperatures.

Watermain failures associated with construction methods were the second most common category of responses (19.3% of responses). This category includes rocks in the backfill, tamping of bedding

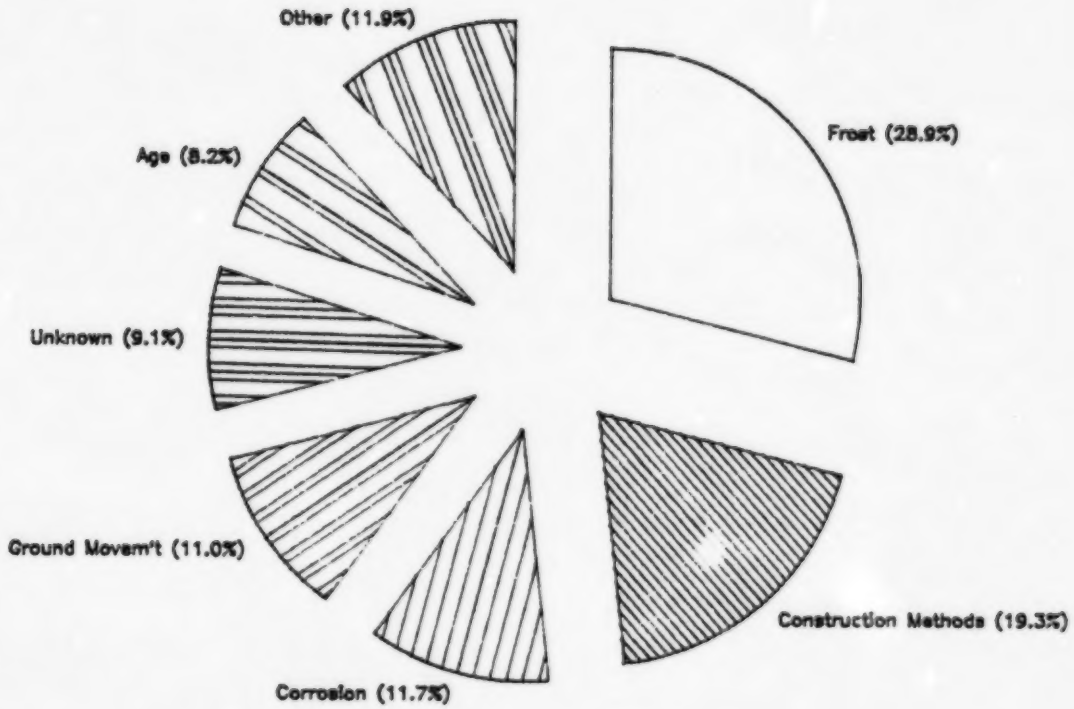

Fig. 9. A percentage breakdown of reported reasons for watermain failures.

either poor or absent, etc. It also includes a few responses which imply that failures were due to adjacent construction (these problems may have been unavoidable). Interestingly, corrosion was only the third most common reason given for watermain failures (11.7% of responses). This does not imply that corrosion is not an important problem, especially for some large systems, e.g. Scarborough [7].

The distinction between some of the other categories of reasons for watermain failures may not be as clear as might be desired. For example, ground movement (the fourth most common reason given at 11%) includes various types of loss of bedding support (e.g. erosion, differential settlement, etc.) some of which may be associated with construction methods such as poor bed preparation. Age (8.2% of responses) is not a very clear statement of a reason for watermain failures (it could overlap with corrosion), but this response was so common that it was included as a category. The "other" category of responses (11.9% of responses) includes a broad range of responses (some of them not reasons for breaks at all) that could not be fit into any of the categories.

By way of summary, there are four main causes of watermain failures across the Province - frost (at about 30% of responses), construction methods (at about 20% of responses), corrosion and age (material failure - at about 20% of responses), and ground movement (loss of bedding support - at about 10% of responses).

Water Losses

Water lost through leakage from municipal water distribution systems due to the condition of the pipes is of primary concern in this attempt to assess the condition of these systems in Ontario. However, the rate of leakage is not easily determined. Also many systems in Ontario have very little metering. Therefore, the questionnaire requested, instead, the percentage of total flow for a system that is unaccounted for. Unaccountable losses of water can include such legitimate uses of water as fighting fires, watermain flushing, or filling municipal swimming pools, etc. It can also include water losses due to leakage, to watermain breaks or "freeze bleeding"[1] - a less legitimate but, under certain circumstances, necessary use for water. Many of the responses to this question are only estimates.

The number of systems reporting percentages of unaccounted for water in various ranges is shown in Figure 10. The degree of response to this question was not as great as elsewhere in the results. Data was provided for 268 water distribution systems or 56% of the systems in the database. This would seem to indicate that this question was often difficult to answer. However, these 268 systems represent a serviced population of 4,924,609, 83% of the total serviced population in the database. (66% of the total population serviced by communal water systems in Ontario.)

---

[1]Freeze bleeding is the practice of wasting water in the winter season to keep water flowing in watermains or service connections. This flow prevents freezing and resulting breakage.

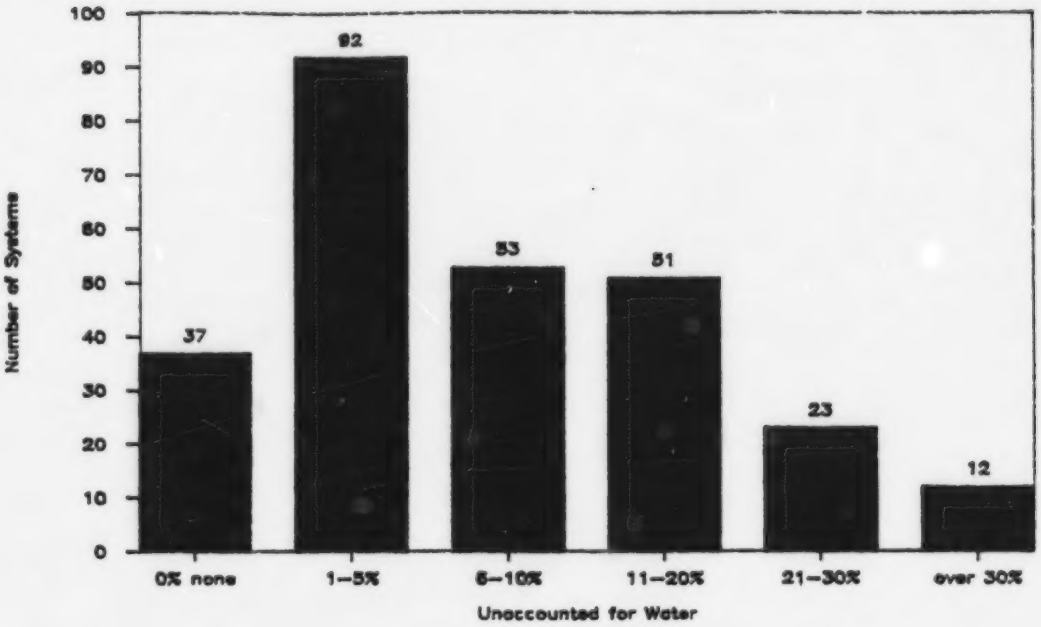

Fig. 10. Water distribution systems categorized according to unaccounted for water as a percentage of total flow.

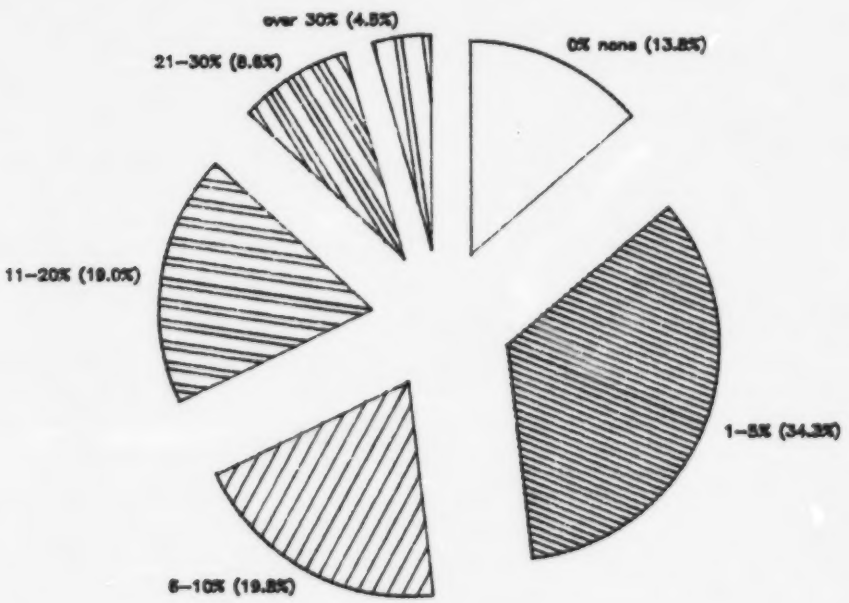

Fig. 11. The percentage of water distribution systems with the above rates of unaccounted for water.

Figure 11 demonstrates the percentage of the 268 systems in each category of unaccounted for water. It should be pleasing to observe that 37 systems or 13.8% of the 268 reporting systems indicated that wastage of water was next to nothing. A further 92 systems or 34.3% of the total systems reported water losses at 1% to 5% of total flow. However, 86 systems or 32% of the total reported water losses above 10%, indicating a considerable waste of resources through lost water.

The 268 systems in the database reporting the percentage of unaccounted for water service 4,924,609 people. The average water loss for these systems (weighted by the serviced population) is 12.5%. If a rehabilitation program across the Province were able to reduce the unaccounted for water losses by one quarter, then the savings would be $4.8 million per year. Table 4 demonstrates how this figure was determined.

Table 4: An Estimate of the Savings Resulting from a 1/4 Reduction in Unaccounted for Water in Ontario

The water lost per year for these 268 systems is (volumes are in imperial gallons):

100 g/c/d x 365 days x 4,924,609 people x 0.125 = 22.5 billon gal.

Since the 268 water distribution systems reporting their rate of water loss represent only 66% of the total water serviced population in Ontario, the total water lost per year should be greater. The total water lost is estimated to be:

22.5 billion gal x 1.52 = 34.3 billion gal.

If half of these losses are due to leakage and "freeze bleeding" and half again of these losses due to leakage or "freeze bleeding" could be eliminated through a rehabilitation program, the reduction in lost water would be:

34.3 billion gal x 0.25 = 8.575 billion gal.

The value of this reduction in lost water at an estimated cost of producing potable water of .56 cents per 1,000 gallons[1] would be:

8.575 billion gal x $0.56/1,000 gal. = $4.8 million/yr.

---

[1]This estimator is an average of the 1985/86 actual variable operating costs per 1,000 gallons for 58 MOE operated water treatment facilities across the Province. This information was provided by C.D. Mialkowsky and D. Atkinson of the Financial and Capital Management Branch, MOE.

2.4 Condition of Ontario Sewer Systems

Combined Sewer

Determining the amount of combined sewer remaining in the province is of interest for several reasons. Combined sewers carry sanitary sewage and storm water. During mild storms, sanitary sewage becomes diluted by rain water entering combined sewers. The total flow treated at sewage treatment facilities as a result increases and operating costs increase accordingly. The efficiency of treatment can be reduced as well due to the dilution of the sewage.

During more severe storms, flows increase so much that sewage may spill into receiving water at combined sewer overflow structures or, out of necessity, be released untreated at sewage treatment facilities. The sewage that is spilled or bypassed is usually dilute but the "first flush" can carry very great pollutional loads. Furthermore, depending on the intensity of precipitation, combined sewers can become surcharged causing sewage to back up into basements.

81 of the 330 sewage collection systems represented in the returned questionnaires have some combined sewer in their systems. Based on the percent of each system that was reported to be combined and the serviced population, it is estimated that there are 4,712 km of combined sewers in these 81 systems.

A minimum estimate of the cost to separate all the combined sewer remaining in the Province would be

the cost to provide storm sewers to relieve all the remaining combined sewer in these 81 sewage collection systems. This cost would be

4,712 km x $605,000.00/km[1] = $2.85 billion.

This is a conservative estimate because the database of returned questionnaires does not include all the sewer systems in the Province which have combined elements.

Infiltration

Infiltration has been defined as "water entering a sewage system and service connections from the ground, through such means as, but not limited to, defective pipes, pipe joints, connections or manhole walls. Infiltration does not include, and is distinguished from, inflow" [9]. The rate of infiltration can depend on the height of the groundwater table relative to sewers. The deleterious effects of infiltration are: it dilutes the sewage, which can reduce sewage treatment efficiency; and it provides a more or less steady increase in flows requiring treatment at treatment facilities.

---

[1]This unit cost estimator [8] is based on a detailed estimate of the cost of local storm sewer construction in the City of York. Sewers ranged from 300 mm to 600 mm in diameter, and construction at various depths was called for. This unit cost estimator does <u>not</u> include the cost of house service connections.

170 of the 330 sewage collection systems represented in the database of returned questionnaires have infiltration problems. Municipalities were asked, in the questionnaire, to report the most important reasons for infiltration for sewage systems with infiltration problems. In Figure 12, the frequency of certain responses concerning causes of infiltration is shown for the 170 sewer systems with infiltration problems.

42% of the responses concerning causes of infiltration involve problems with pipe joints. This is interesting because the leakage at these pipe joints can often be significantly reduced with current rehabilitation techniques. Of the 42% with pipe joint problems, 20% involve deteriorated joints, meaning that the seal at the pipe joint has failed. 11% involve leaking, off-set joints, meaning that the pipe ends have separated at the joint. Another 10% of the joint problems involve open joints, referring to the practice, mostly in older types of pipe installations, of not providing a seal at the pipe joint at all.

23% of infiltration problems are caused by the structural failure of the sewer pipe. Cracked pipe represents 17% of the responses given concerning causes of infiltration, while broken or collapsed pipe represents another 6% of the causes of infiltration. Although the leakage caused by these problems can be significantly reduced with current rehabilitation techniques, pipe replacement may be a more feasible alternative solution in some cases.

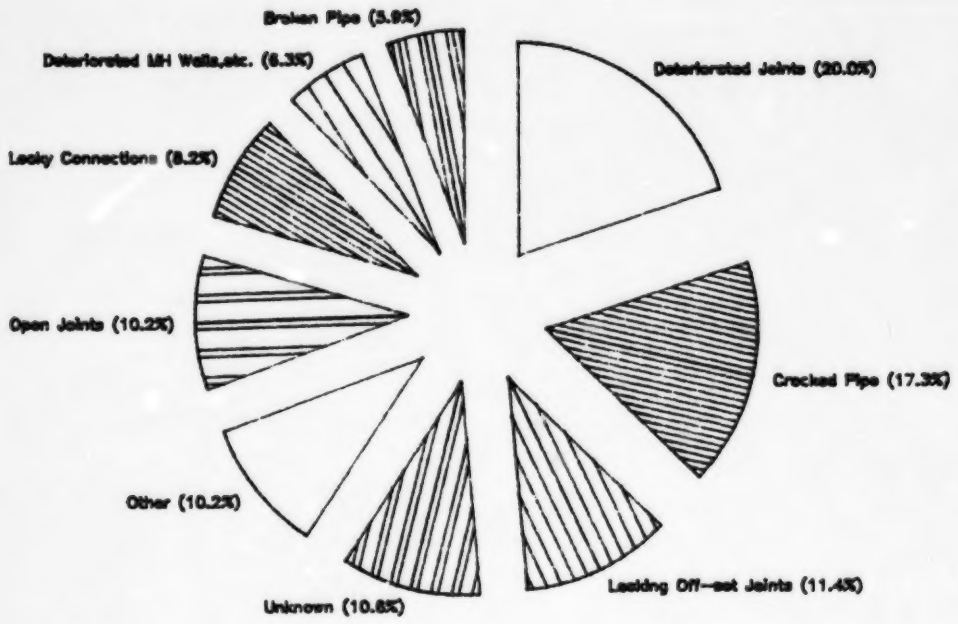

Fig. 12. A percentage breakdown of reported causes of infiltration into sewer systems.

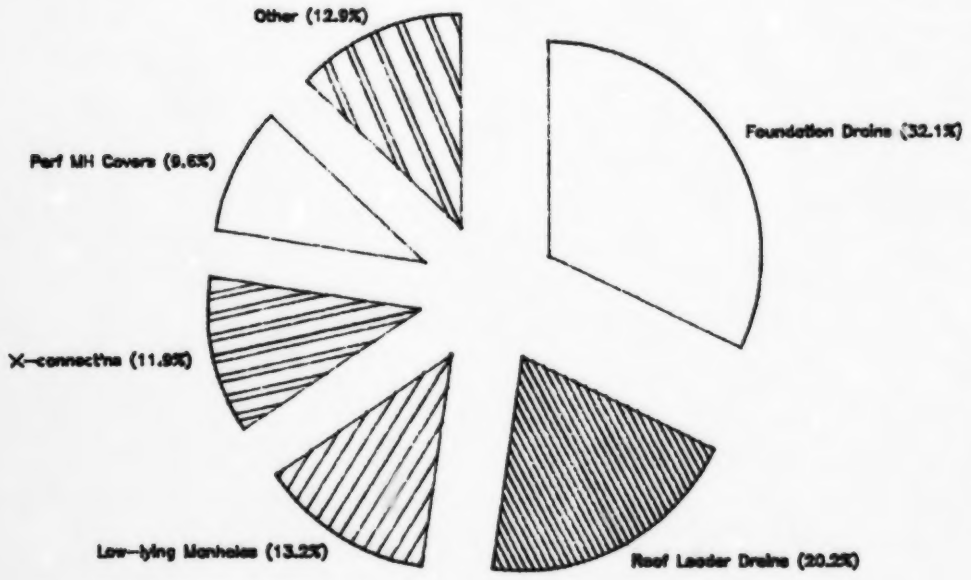

Fig.13. A percentage breakdown of reported causes of inflow into sewer systems.

8% of infiltration problems are caused by leaking house service connections. This is a very important aspect of the infiltration problem, since the total length of service connections often equals the length of the sewage collection system. (Leaking house service connections are probably a more important problem than the 8% rate of response above would indicate.) Finally, 6% of infiltration problems are caused by deteriorated manhole walls, bases and troughs.

Inflow

Inflow has been defined as "water discharged into a sewer system and service connections from such sources as, but not limited to, roof leaders, cellar, yard and area drains, foundation drains, cooling water discharges, drains from springs and swampy areas, manhole covers, cross connections from storm sewers and combined sewers, catch basins, storm water, surface run-off, street washes or drainage" [9]. A sanitary sewer system will behave like a combined sewer system if it has a significant inflow problem. The same problems occur: increased flows resulting in increased treatment costs; untreated releases of sewage at overflow structures in the sewer system or at the treatment plant; and, possibly, flooding of basements. Inflow is the result of the ways in which the sewage collection system is used, and, unlike infiltration, is not a result of structural problems in pipes.

207 of the 330 sewage collection systems for which information was provided have inflow problems. The

pie chart in Figure 13 graphically demonstrates the frequency of the major causes of inflow for the 207 systems with inflow problems.

Of the major causes of inflow reported for these 207 systems, 32% are reported to be foundation drains connected to the sewer system. This is generally a very expensive problem to remedy because the disconnection of these foundation drains requires extensive excavations, mostly on private property.

However, the other major causes of inflow are less difficult to remedy. Roof drains (20.2% of the reported causes of inflow) are relatively inexpensive to disconnect. However, disconnection of roof drains can aggravate flooding problems if they exist. Problems at the top of manholes are also relatively inexpensive to solve. 23% of reported causes of inflow involve manholes - either perforated manhole covers (9.6% of reported causes) or low lying manholes (13.2% of reported causes). Finally, 12% of the major causes of inflow involve cross connections from storm sewers. Disconnection of these inputs would involve excavations. However, these excavations would be fewer in number than those required to disconnect foundation drains, and they would be mostly on public property.

Compounded Problems

The problems of infiltration, inflow and combined sewers tend to overlap. For instance, of the 170 sewage collection systems that have infiltration

problems, 147 have inflow problems as well. Furthermore, of the 170 sewage collection systems with infiltration problems, 54 systems have combined sewer elements in the systems and inflow problems as well.

This compounding of problems poses a special question with regard to a rehabilitation program for aging and deteriorating sewers in Ontario. The rehabilitation of these sewers, through reducing infiltration, would achieve the goal of extending the useful life of these facilities, but might only partly achieve the goal of reducing extraneous flow. It may be that, in many cases, the goal of reducing extraneous flows would be better served by reducing inflow or eliminating remaining combined sewers. This, however, does not involve rehabilitation of existing facilities but rather policy decisions regarding the strict enforcement of sewer use by-laws or the construction of storm sewers to relieve remaining combined sewers.

It is suggested that a rehabilitation program for Ontario sewers should address these issues.

Cost of Treating Extra Flows

The 147 systems which have both inflow and infiltration problems have a total sewer serviced population of 3,160,327. The total annual sewage treated for these systems is estimated to be 146 billion imperial gallons, of which 30.7 billion imperial gallons is estimated to be extraneous flow (inflow and infiltration). If half of this

extraneous flow could be eliminated through a Province-wide rehabilitation program (that includes efforts to eliminate inflow), $5 million per year in operating costs for sewage treatment could be saved. If the sewage systems not included in this database are considered as well, the savings could be as high $6.4 million per year. The details of these calculations are in Table 5.

Table 5: Cost of Treating Extra Flows

The 147 sewage collection systems with inflow and infiltration service 3,160,327 people. The annual sanitary sewage flow is estimated to be

3,160,327 people x 100 imp. gal/C/D x 365 days
= 115.35 billion imp. gal.

The extraneous flow for these systems is estimated to be 21% of the total flow (sanitary sewage flow plus extraneous flow) [10]. The total annual flow is then

115.35 billion imp. gal x 1.2658
= 146 billion imp. gal.

The total annual extraneous flow is

146 billion imp. gal - 115.35 billion imp. gal
= 30.7 billion imp. gal.

If one half of this extraneous flow could be eliminated from these 147 sewer systems through a rehabilitation program, then the savings in annual sewage treatment operating costs would be

30.7×10^9 imp. gal x 0.5 x $.33/1,000 imp. gal[1]
= $5,557,250.

For all of Ontario's sewer systems, the savings could be as high as

$5,557,250/year x 1.26 = $6,372,135/year.

---

[1]This estimator of the cost of sewage treat ent is the average of the actual 1985/86 variable operating costs per 1,000 imp. gal for 128 MOE operated sewage treatment facilities.

2.5 Concerns of Ontario Municipalities

This consideration of the condition of water distribution and sewage collection systems in Ontario would not be complete without presenting the opinions and concerns with regard to the condition of these systems of the municipal officials themselves who took the trouble to complete the questionnaire. These concerns were expressed in the questionnaire in answers to questions regarding: the rank order of importance of various problems affecting water distribution systems; the present condition of water and sewer systems; and the relative change in condition of water and sewer systems over the last 15 years. An analysis of the data provided in these questions follows.

The municipalities completing the questionnaire were asked for their water distribution system(s) to rank in order of importance such concerns as low pressure, poor water quality related to the condition of system pipes, leakage, watermain break frequency or any other concern. Figure 14 graphically demonstrates the frequency with which these concerns were given first priority for the 300 systems for which information was provided. Not surprisingly, concerns over poor water quality were considered most important most often (29.5% of responses). However, it may be that for some of these responses the cause of the poor water quality is at the water source and not in the distribution system.

Watermain break frequency (ranked first in 21.9% of the responses) and low pressure problems(ranked first in 19.7% of the responses) are of about equal concern. Low pressure problems in the water

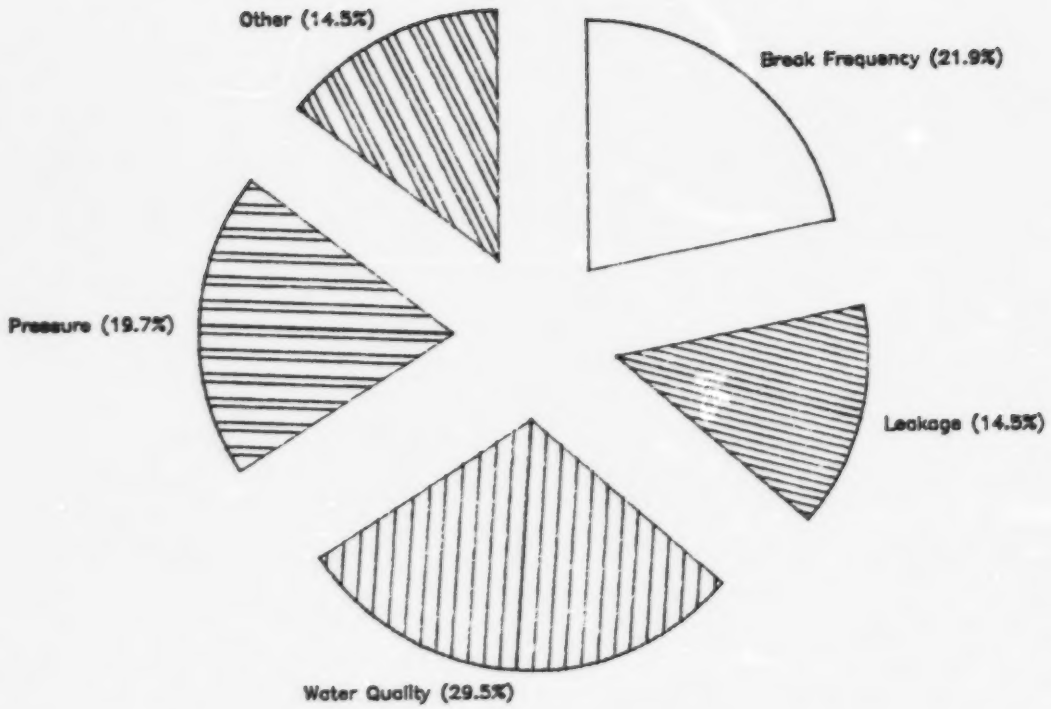

Fig. 14. Areas of primary concern for water distribution systems.

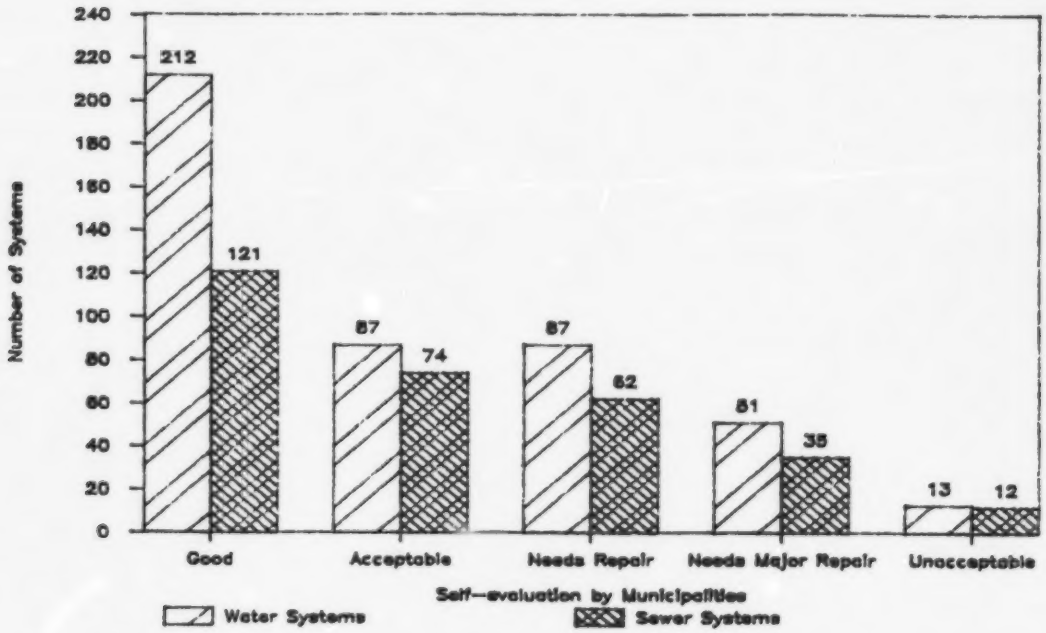

Fig. 15. The present condition of water and sewer systems.

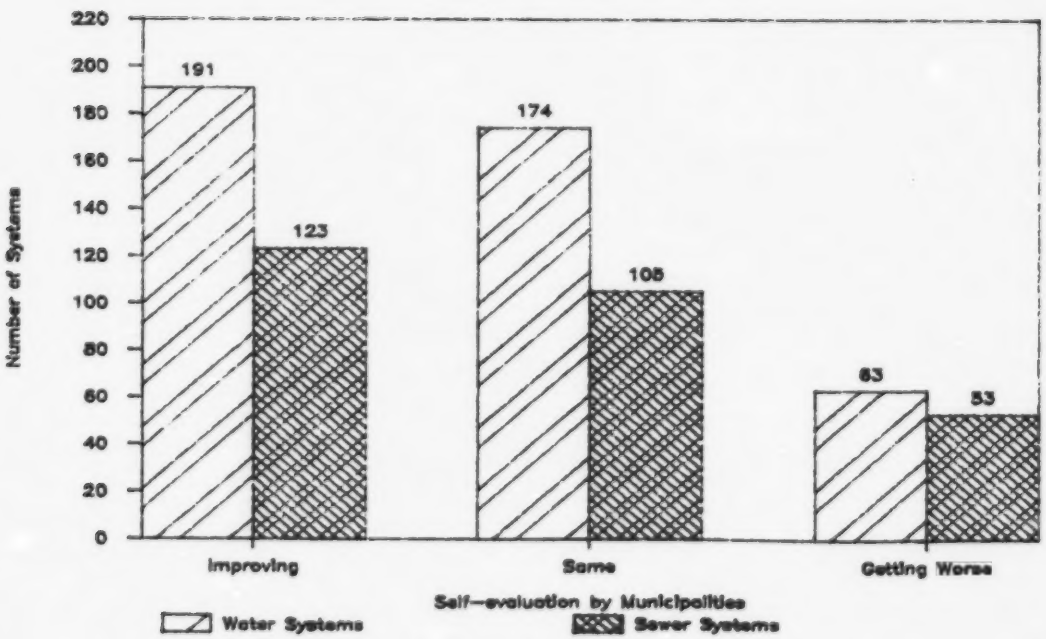

Fig. 16. For water and sewer systems, the change in condition over the last 15 years.

distribution systems in small Ontario communities are often due to the presence of old, small diameter, cast iron watermains.

Leakage was considered most important for just 14.5% of the systems. Also, for 14.5% of the systems some other problem was of greatest importance. This (other) category covers a broad range of responses.

The opinions of municipal officials with regard to the present condition of their water distribution and sewage collection systems are categorized and presented in Figure 15. 299 water systems and 195 sewer systems are considered to be in good or acceptable condition. 87 water and 62 sewer systems a e considered to need some repairs. Finally, 64 water systems and 47 sewer systems either need extensive repairs or are in unacceptable condition.

It would be expected that a majority of the systems would be in either good or acceptable condition, especially considering how many systems have been constructed relatively recently. In these results, 66% of water systems and 64% of sewer systems are considered to be in either good or acceptable conditions. However, the fact that over 30% of water and sewer systems in the returned questionnaires (and by inference in the entire Province) need some repair or need extensive repair or are in unacceptable condition would seem to warrant attention on the part of senior governments to the matter of encouraging the rehabilitation of these systems.

In Figure 16, the opinion of municipal officials with regard to the change in condition of their systems

over the past 15 years is depicted by category. The condition of 191 water and 123 sewer systems is reported to be improving. For 174 water and 105 sewer systems, the condition is reported to have stayed the same. However, for 63 water and 53 sewer systems, the condition has been getting worse.

It would seem that there might be considerable reluctance on the part of municipal officials to admit that the condition of their water or sewer systems has been getting worse in recent history. It is, therefore, relatively surprising that the condition of as many as 63 water and 53 sewer systems is seen to have been worsening. This is quite probably indicative either of severe problems with these systems or of substantial financial obstacles to the solution of these problems.

3.0 THE SITUATION IN SMALL ONTARIO MUNICIPALITIES

3.1 The State of Current Information on Water and Sewer Systems

In the process of collecting detailed inventory information from over 70 small Ontario municipalities, the Project Team was able to learn a great deal about the type and quality of information that is kept on water distribution and sewage collection systems in small municipalities.

Very few of these municipalities have detailed inventories of their water distribution and sewage collection systems that include length and diameter of pipes, material of construction, and the age of the pipes. However, every municipality does have system plan maps from which the length and diameter pipes can be determined. Sometimes these plans are coded according to the pipe material of construction.

The present Works Department officials in small Ontario municipalities have often inherited a situation resulting from the methods of record keeping of their predecessors. It was very common for the project staff to hear recounted a story of how the former Superintendent of Works had recently retired taking with him the only real detailed inventory of the system in his head.

As a result, a detailed inventory of a sewer or water system must often be completed by determining the length and diameter of system pipes from plan maps.

However, to determine the material of construction, it is often necessary to rely on Works Department official's personal knowledge of pipe materials in use in various streets gained through years of experience with their systems.

Records of the age of system pipes are almost never kept. However, Works Department officials may be able to estimate the age of system pipes. The accuracy of these estimates decreases with the age of the pipe and increases with the number of years of experience of the Works Department official. Otherwise, contract documents and Council resolutions authorizing construction can be used to date parts of water distribution or sewer systems. Failing this, if records are incomplete, the age of sections of water or sewer systems can be estimated by assuming that the development of these systems followed the same pattern as the historical development of the municipality.

Service records for system elements are also often incomplete or absent. This means that there are sometimes no records to show which system elements have the worst history of failure and should be targeted for early rehabilitation or replacement. This lack of information impedes pro-active maintenance and, coupled with the lack of information on pipe ages, prevents the prediction of the useful life of system components.

Micro-computers are being used increasingly to lighten this burden of maintenance record keeping in the Public Works Departments of large municipalities. However, very few of the Works Departments in small

municipalities were using micro-computers at the time when the Project Team visited them.

The reader should note, by way of providing a balanced picture of the situation in small municipalities, that the systems are small, and it is possible for municipal officials to have a good understanding of their systems without extensive record keeping. By way of contrast, this sort of understanding, e.g. knowing which system components should be repaired or renewed when funds become available, would only be possible in a large municipality through extensive record keeping. Furthermore, many of the small municipalities visited by the Project Team were in possession of a relatively recent report by a consulting engineering firm concerning their system's deficiencies and suggesting a path of remedial action.

3.2 Cost and Extent of Current Maintenance and Rehabilitation Activities

It had been hoped at the time that this study was designed that it would be possible to establish benchmark costs for maintenance and rehabilitation activities in small Ontario municipalities. However, with some exceptions, it proved to be a difficult task to gather information on the cost of current maintenance and rehabilitation activities in small Ontario municipalities. This was not due to the inadequacy of the records, but rather, due to the accounting practices currently in place in these municipalities.

Currently, these small Ontario municipalities prepare financial statements so that the information that they contain will satisfy the requirements of the "Financial Information Return" filed with the Ministry of Municipal Affairs, or otherwise, so that the information will satisfy the requirements of Council, or for both reasons.

Unfortunately, the costs of maintenance and rehabilitation activities often are aggregated with all other costs attributable either to water or sewer operating costs or to water or sewer capital costs. This makes it difficult to determine costs specific to maintenance or rehabilitation activities. It would be possible to determine these costs by going through the archives of work orders. Unfortunately, this is a laborious task and the work order records are not always kept.

Nonetheless, many of the small municipalities visited by the project staff attempted to estimate the costs of maintenance and rehabilitation activities for their water distribution or sewage collection systems for the most recent year (in this case, 1984). Average costs per person serviced for these activities based on the estimates that were provided are presented in Table 6

It is important to note that the average costs per person serviced for the various activities in Table 6 are average costs for only those municipalities that were able to estimate their costs.

TABLE 6: AVERAGE MAINTENANCE AND REHABILITATION COSTS (WATER AND SEWER SYSTEMS)

	WATER		SEWER	
Activity	Average Cost Per Person Serviced	No. of Systems	Average Cost Per Person Serviced	No. of Systems
Repairs and Maintenance	$ 8.36	57	$ 7.30	52
Renovation Costs	$ 2.81	6	$12.77	5
Replacement Costs	$17.89	24	$17.51	13

The average cost per person serviced for repairs and maintenance was higher for water systems ($8.36) than for sewer systems ($7.30).

Average renovation costs per person serviced are higher for sewer systems than for water systems. However, the number of systems that are able to provide renovation costs are so few that it would be dangerous to draw conclusions from these average costs per person serviced. The term renovation is used here to describe various in-situ techniques of restoring the capacity of watermains or sewers or extending their useful life (e.g. cleaning and lining of watermains or slip lining or grouting of sewers). Very little renovation work has been done in recent years in most of the small municipalities visited by the project staff.

The average renovation cost in Table 6 for water systems ($2.81/person serviced) includes costs for small amounts of cleaning and lining of watermains. The average renovation cost for sewer systems ($12.77/person serviced), on the other hand, includes costs for more substantial programs for the elimination of inflow and infiltration in a few municipalities.

The average costs per person serviced for replacements in Table 6 are similar for sewer systems and water systems. The average cost per person serviced for replacing pipe in 13 sewer systems was $17.51. This compares with an average cost of $17.89/person serviced for 24 water systems. Replacement activity is reported for fewer sewer systems than water systems probably because construction activity for sewer systems in small

municipalities usually requires the authorization of the Municipal Council and often depends on government grants. It is not surprising that this construction activity (e.g. the replacement of pipe) should be less frequent than construction activity for water systems. Pipe replacement for small water systems is often financed through a reserve fund. Consequently, it is possible to carry out replacement activity on a steadier basis.

3.3 Sewer Use By-Laws

In an effort to gain a better understanding of the inflow problem in small Ontario municipalities, the project staff performed a telephone survey of 25 small municipalities known to have inflow problems in their sanitary sewer systems due to the presence of roof leader drains and foundation drains connected to the system. The staff inquired whether or not sewer use by-laws were in existence that prohibited the connection of these drains to the system. If such sewer use by-laws were in place, the staff inquired about problems with the enforcement of these by-laws.

The results of this survey are presented in Table 7. Only one of the 25 municipalities has not enacted sewer use by-laws governing these connections. The reason given for the absence of a by-law is that the disconnection of roof leader and foundation drains would aggravate an already critical drainage problem arising from the poor drainage characteristics of the clay soils in the municipality and the absence of storm sewers.

TABLE 7: EXISTENCE AND ENFORCEMENT OF SEWER USE BY-LAWS (IN 25 SMALL MUNICIPALITIES WITH INFLOW PROBLEMS)

Number of Municipalities	By-Laws In Existence	Reason for Absence of By-Laws or Problem With Enforcement
1	No	Poor drainage in clay soils. Storm sewers absent.
7	Yes	The by-law is enforced. Implies that the municipality is attempting to solve the problem.
5	Yes	There are no storm sewers.
5	Yes	Connections were made prior to the creation of the by-law. The by-law is not retroactive.
4	Yes	Enforcement of the by-law would be too politically sensitive.
2	Yes	Enforcement of the by-law would be too costly for residents.
1	Yes	Inadequate staff to enforce by-law.

24 of the small municipalities have sewer use by-laws in place. Seven of these municipalities state that their by-laws are enforced, implying that they are attempting to remedy the inflow problem, but have not, as yet, succeeded in eliminating inflow altogether.

Five of the municipalities state that the reason for the lack of enforcement of the sewer use by-law is the absence of storm sewers. This implies that these municipalities feel that disconnection would aggravate flooding problems. Another five municipalities state that their sewer use by-law is not retroactive and, therefore, does not mandate the disconnection of drains hooked up to the sewer system prior to the enactment of the by-law.

Four municipalities indicate that the enforcement of the sewer use by-law would be too politically sensitive. This is, no doubt, due to the expense to residents that would be incurred in disconnecting these drains. Two other municipalities state this directly; that the enforcement of the sewer use by-law would prove too costly for residents in the municipality.

Finally, one municipality indicates that they do not have adequate staff to enforce their by-law.

The cost of disconnecting foundation drains is significant and it is not surprising that the issue should be "politically sensitive". Furthermore, most of the costs would normally be carried by the property owner. The cost of disconnection is similar to the cost of providing a storm sewer service

connection, $6,400/connection [9]. (This assumes that storm sewers are present.)

It may be that a more feasible method for combating inflow problems across the province would be first to disconnect roof leader drains and remedy the problems of low lying manholes and perforated manhole covers before attempting to disconnect foundation drains. The merit of disconnecting foundation drains should be decided for each municipality in conjunction with their consultant based on the specific situation in the municipality.

3.4 A Special Consideration

Many of the small municipalities that were visited by the project staff suggested that special consideration be given to attempting better co-ordination of grant programs of various Ministries of the Ontario Government that affect municipal public works infrastructure. Many of these municipalities have had the experience of receiving, for example, funds from the Ministry of the Environment for the replacement of watermains and sewers on a given street just after completing the resurfacing of the road with the help of funds from the Ministry of Transportation and Communications. These municipalities are grateful for all the help that they receive from the Ontario Government. However, they suggest that sometimes grant funds could be more efficiently spent and would go further if there were greater co-ordination of programs.

4.0 REFERENCES

1. Choate, P. and S. Walter, America in Ruins: Beyond the Public Works Pork Barrel, Council of State Planning Agencies, Washington, D.C., 1981

2. Curtis, W.H. et al, "Canada's Urban Infrastructure: Physical Condition and Funding Adequacy", Federation of Canadian Municipalities, 1984

3. MacLaren, J.W., "Report to the Ministry of the Environment of the Province of Ontario on a Water Distribution and Sewerage Rehabilitation Program for Ontario Municipalities", unpublished

4. National Inventory of Municipal Waterworks and Wastewater Systems, Canada Department of Supply and Services, Ottawa, 1982

5. Municipal Water and Wastewater Treatment Works in Ontario, Ontario Ministry of the Environment, 1984

6. O'Day, D.K., "Organizing and Analyzing Leak and Break Data for Making Main Replacement Decisions", J.A.W.W.A., 1982, p. 589-594

7. Doherty, B.J., "Ductile Iron Water Main Corrosion in the City of Scarborough", AWWA/OMWA Joint Annual Conference, Toronto, 1985

8. "Feasibility Study and Costing of Proposed Pollution Control Measures in the Humber Sewershed", Paul Theil Associates Ltd., Bramalea, 1985

9. Existing Sewer Evaluation and Rehabilitation, ASCE and WPCF, New York, 1983

10. Zukovs, G., "WPCP Extraneous Volumes in the Province of Ontario and Associated Treatment Costs", Ontario Ministry of the Environment, unpublished

APPENDICES

Ministry of the Environment
Ministère de l'Environnement
Ontario

Environmental Approvals and Project Engineering Branch

135 St. Clair Avenue West
Suite 100
Toronto, Ontario
M4V 1P5

135 ouest, avenue St. Clair
Bureau 100
Toronto (Ontario)
M4V 1P5

965-6963

Date:

Official:

Department:

APPENDIX 1

Address:

Town:

Postal Code:

Dear _____,

The Ministry is interested in protecting the considerable investment that all Ontarians have in their water infrastructure. Therefore, we are making an attempt to determine the approximate age and relative condition of the underground services (the watermains and sewer pipes) in all of Ontario. With this information, the Ministry can determine what measures need to be taken. This work is being undertaken by the staff of our water and sewage system rehabilitation project.

Your co-operation in filling out this short survey form is greatly appreciated. Please use your judgement to provide the best estimate possible where necessary and if an answer is simply not known please indicate that this is the case. A self addressed envelope has been included for your convenience.

Yours very truly,

John Elstad
Project Leader

Phil Joseph
Project Manager

JE/vr

SUGGESTED TERMS FOR USE IN ANSWERING QUESTIONS 5.b. and 5.c.

SOURCES OF INFLOW

Usually in the Collection System

Low-lying manholes
Perforated manhole covers

Cross connections (from separated sewers)
Back flow from receiver

Drains from springs and swampy areas

Usually on Private Property

Roof leader drains
Foundation drains
Yard drains
Area drains
Cooling water discharges

SOURCES OF INFILTRATION

Collapsed pipe

Broken or crushed pipe

Cracked pipe

Deteriorated pipe joints

Leaking off-set joints

Open joints

Deteriorated mortar joints in brick pipes

Leaking house service connections

Faulty taps between sewers & manholes

Faulty taps between service connections and main sewers

Collapsed manhole and wet walls

Deteriorated manhole walls, bases and troughs

Deteriorated mortar joints in brick manholes

Deteriorated wet wells and pumping station structures

Other sources such as deteriorated regulators, tide gates, etc.

MOE SHORT SURVEY FORM 1 APPENDIX 1 (cont.)

Name of Municipality: _____

District, Region or County: _____

Department: _____

Name and Title of Person Completing the Survey: _____

Mailing Address: _____

_____ **Postal Code:** _____

Telephone: _____ **Date Mailed:** _____

(Please correct any errors in the above information.)

Date Completed (by Respondent): _____

1. Serviced population: water _____

   sanitary sewer _____
   (separate or combined)

2. Water distribution system:

   a) Approximate age of oldest section: _____;

   b) Proportion of system that is
   25 - 50 years old _____%,
   over 50 years old _____%.

3. Sanitary sewer system (separate or combined):

   a) Approximate age of oldest section: _____;

   b) Proportion of system that is
   25 - 50 years old _____%,
   over 50 years old _____%.

4. Water distribution system:

   a) Approximate total length of pipe in system
   (please specify feet or metres): _____

   b) Most common pipe material: _____

   c) Number of pipe breaks per year: _____

   d) Reason for pipe breaks: _____
   _____

   e) Unaccounted for water:
   water billed/water pumped _____
   or, estimate percentage lost _____%

f) Rank in order of importance the following areas of concern for your water distribution system (1 - most concern, 5 - least concern):

Break Frequency _____ Leakage _____
Water Quality Problems _____ Pressure _____
(caused by pipes)
Other (specify) _____

5. Sanitary sewer system

a) Percent combined _____% Percent separated _____%

b) Do you have an inflow problem? _____
Main cause(s) of inflow problem (refer to back of covering letter, choose no more than 2):

_____

c) Do you have an infiltration problem? _____
Main cause(s) of infiltration problem (refer to back of covering letter, choose no more than 2):

_____

d) By what percentage have flows increased because of the problem? _____%

e) How often? _____

6. General:

a) Are there any health or environmental problems occurring because of the condition of the pipes of either system? Briefly explain. _____

_____

_____

b) Is growth being limited because of the condition of the pipes of either system? Briefly explain.

_____

_____

7. In your opinion, the present condition of your water and sewer system can be described as:

Facility	Present Condition*	Change in Conditions Over the Last 15 Years (check one only)		
		Improving	About the Same	Getting Worse
water distribution				
sewage collection				

* 1 is good, 2 is acceptable, 3 needs some repair, 4 need extensive repair, 5 is not acceptable, 6 is not existing, or under another jurisdiction.